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ATTENTION AND GENERALIZATION DURING A CONDITIONAL DISCRIMINATION[1]

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A conditional discrimination was established and analyzed, using four pigeons. The discrimination was among four compound stimuli projected on the response key—a white circle or triangle on a red or green background—during two conditions of illumination in the chamber, no illumination or flashing illumination. The two lighting conditions indicated whether the stimuli on the key containing triangles or those containing red would be the occasion for reinforcement. After the discrimination formed, generalization to intermediate and extreme values of the conditional stimulus and the attention of the birds to separate aspects of the stimulus on the key under each of the conditional stimuli were studied. All subjects generalized across values of the conditional stimulus, the lighting of the chamber. But subjects differed in the manner in which they treated the compound stimuli: two tended to attend to one or the other aspect of the stimulus on the key depending on the conditional stimulus, and two offered no evidence of such selective attention. Thus, the differential control of responding by the conditional stimuli cannot be attributed to a shift in attention between the figure and ground aspects of the compound stimuli.

Attention is a functional concept, defined in terms of the correlation between changes in the environment and in behavior. An organism attends to a feature of its environment if changes in the feature bring about changes in behavior; it does not attend to a feature of the environment if changes in the feature do not bring about changes in behavior. Attention is closely related to stimulus control and to generalization. An organism is said to attend to those stimuli or aspects of stimuli that control its behavior. A non-constant gradient of generalization implies attention to at least one of the environmental aspects that were changed in measuring the gradient, and a flat, constant gradient implies inattention to all of the changed aspects. For example, Jenkins and Harrison (1960) showed that the naive pigeon may be initially inattentive to its auditory environment (a flat gradient) but attentive (a non-flat gradient) after some experience, in that case differential reinforcement, with auditory stimuli.

Selective attention occurs when not all aspects of a stimulus are in control of behavior. It is clear that reinforcement in the presence of a stimulus with more than one independently manipulatable aspect does not guarantee that all aspects of the stimulus will individually come to control the organism's behavior (*e.g.*, Reynolds, 1961). But attention to more than one aspect of a stimulus may occur, as when variation of two aspects of a stimulus produces a greater decrement in responding than does variation of only one aspect (*e.g.*, Butter, 1963). What it is that directs and sustains the organism's attention has been little studied.

The present study attempted to control attention to either the figure or the ground of a series of stimuli by means of two additional, conditional stimuli. These two stimuli establish a conditional discrimination by setting the occasions on which either the figure or the ground of the series of stimuli is consistently associated with reinforcement or extinction. Further, this study attempted to analyze the function of the conditional stimulus by examining generalization to various values of it and to demonstrate directly that the control by the conditional stimuli cannot in this case be accounted for by a shift in the pigeons' attention between the figure and ground of

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the series of stimuli depending on the value of the conditional stimulus.

METHOD

Subjects

Four adult male White Carneaux pigeons were maintained at 80% of their free-feeding weights. Each bird had several months of experience with the present procedure, except that auditory conditional stimuli were used and no tests of attention were made.

Apparatus

A standard chamber for conditioning the pigeon's operant behavior contained one key that could be operated by an effective force of 15 g. Reinforcement consisted of 3.5-sec access to mixed grain in a magazine located beneath the key. The key could be illuminated from behind with a white triangle, white circle, red background, or green background, either separately or in any combination. The houselight could be flashed at rates of 0.2, 0.5, 1.0, 2.0, 3.0 flashes per sec or not illuminated at all. Each flash was about 50 msec in duration. Standard scheduling and recording apparatus were located in a separate room.

Procedure

The procedure consisted of three parts: training on the conditional discrimination, measurement of generalization to intermediate and extreme values of the conditional stimulus, and the assessment of the direction of attention under the two values of the conditional stimulus used in training.

Formation of the discrimination. The birds were transferred directly from an auditory conditional discrimination to the following discrimination. They were exposed in each session to a total of eight stimuli consisting of four stimuli presented on the key, and for each stimulus on the key either no illumination of the houselight or flashes of the houselight at a rate of 2 per sec (the conditional stimulus). The stimuli on the key were the white triangle on a red or green background and the white circle on a red or green background. Each stimulus was presented for 2 min at a time, and there were eight presentations of each stimulus in a session, to a total session duration of 128 min. The stimuli were presented in three different orders from session to session, to a total of 15 sessions, when an adequate discrimination had formed.

Reinforcement was on a VI 1-min schedule in the presence of stimuli containing the triangle when the houselight was flashing and in the presence of stimuli containing red if the chamber were dark. Thus, the stimuli-reinforcement correlations called for the pigeon to peck at the triangle on either a red or green background in the presence of flashing light and at the red background with either the triangle or circle as figure when the box was dark.

Measurement of generalization. In extinction, during each of two successive sessions the four stimuli on the key were each presented twice for 1 min each in the presence of each of the following conditions of lighting in the chamber: no light or flashing light at the original rate of 2 per sec; flashing light at the faster rate of 3 per sec; or flashing light at the rates of 0.2, 0.5, or 1.0 per sec. Each combination of light condition (six) and stimulus on the key (four) was presented twice on each day. The order of presentation was irregular with respect to both the light conditions and the key stimuli, except that no combination was repeated the second time until all had been presented once. A different irregular sequence was used in each session. The data consisted of the rates of responding in the presence of each of the 24 stimuli based on a total of 4 min of exposure to each stimulus.

Assessment of attention. After several sessions of reinforcement on the original procedure, interest turned to the specific aspect of the stimuli on the key that controlled the birds' behavior under the two conditional stimuli. The separate aspects of each stimulus, the triangle or circle on dark (unilluminated) backgrounds and the red and green backgrounds without figures, were presented singly with either no light in the chamber or with the light flashing at 2 per sec. Each stimulus was presented for 1 min twice during the session in a different irregular order each time, and the total number of responses in the presence of each was counted. No responses were reinforced.

RESULTS AND DISCUSSION

Formation of the discrimination. The conditional discrimination arranged for by the

procedure developed more rapidly than one reported earlier (Reynolds, 1961), probably because of the experience of these subjects with the stimuli on the key, but the results are similar. After 15 sessions, all four pigeons responded predominantly in the presence of the triangle on a red or green background when the houselight was flashing (at 2 per sec) and predominantly in the presence of stimuli containing a red background with either a triangle or circle as figure when there was no light in the chamber. Thus, the birds responded to the triangle on the red background under both conditions, they responded little to the circle on a green background in either condition, and they responded to the circle on the red background and the triangle on the green background predominantly during the conditional stimulus that set the occasion for reinforcement in their presence.

Measurement of generalization. This portion of the experiment studied responding in extinction in the presence of each stimulus on the key during presentation of various values of the conditional stimulus covering a range from no illumination to three flashes of the houselight per second. Figure 1 shows, in a separate panel for each bird, the number of responses per minute emitted in the presence of each stimulus on the key as a function of a logarithmic scale of the rate of flashing of the houselight in the chamber. The triangles and circles denote responding in the presence of stimuli containing those figures, and filled and unfilled points denote responding in the presence of stimuli with red or green backgrounds, respectively. Dotted lines connect the data at two and at three flashes per second, a rate of flashing greater than that used in training.

Notice first that despite rates of responding around 40 per min by some pigeons in the presence of stimuli previously associated with extinction, the discrimination of all four pigeons is preserved in extinction. When there was no illumination in the chamber (N in the figure), the rate of responding was consistently highest in the presence of stimuli containing a red background (filled points), and when the light was flashing at 2 per sec, the rate of responding was consistently highest in the presence of stimuli containing a triangle (triangles).

While there are individual differences between pigeons, there is also evidence of generalization to intermediate values of the conditional stimulus. This is most evident for the two stimuli that had been differently associated with reinforcement under the two values of the conditional stimulus. As the rate of flashing increased toward 2 per sec, all four birds responded less in the presence of the circle on a red background (filled circles) and more in the presence of the triangle on a green background (unfilled triangles) than they did under conditions of no illumination, although the changes in these curves are by no means consistently monotonic. Each bird found a point of approximate response equality in the vicinity of 0.5 flashes per sec.

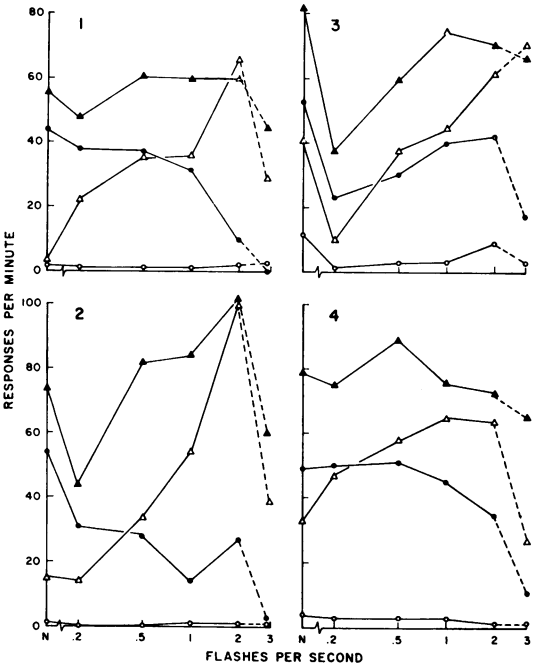

Fig. 1. Gradients of generalization for four pigeons. The number of responses per minute in extinction in the presence of each stimulus on the key as a function of a logarithmic scale of the rate of flashing of the houselight in the chamber. N indicates darkness. Triangles and circles in the graphs indicate that the stimulus on the key contained a triangle or a circle; filled points or unfilled points, that the stimulus on the key had a red or green background.

There is also an indication of generalization in the rates of responding obtained in the presence of a triangle on a red background, which had been consistently associated with reinforcement both in the presence of no illumination and two flashes of the houselight

per second. All birds responded less frequently at 0.2 flashes per sec than at no illumination and all responded less frequently at 3.0 flashes per sec than at 2.0 flashes per sec. However, only one bird (2) responded less frequently at 1 than at 2 flashes per sec.

There are, on the contrary, no indications in these data of enhanced responding in the presence of the circle on green, the stimulus consistently associated with extinction, for either intermediate or extreme values of the conditional stimulus. Birds 1, 2, and 4 did not respond more in the presence of conditional stimuli not previously used in training, but since their overall tendency to peck at the circle on green was so low, it is impossible to say whether or not any of these values of the conditional stimulus control a lower rate of responding. Bird 3, however, exhibited a substantial rate of responding both with no illumination and with 2 flashes per sec. For this bird, the rates controlled by the intermediate values and the extreme value of the conditional stimulus are clearly lower. This effect is also seen in the decrease in the responding of all four birds in the presence of the circle on red when the conditional stimulus was changed from 2 to 3 flashes per sec.

There was no indication either during training or during the measurement of generalization of a correlation between responses and individual flashes of the light. Although flashing light clearly served as a stimulus in this experiment, there was no tendency to respond or not respond predominantly during or just after individual flashes. Increases and decreases in the number of individual flashes cannot therefore be appealed to in accounting for these data.

These data demonstrate that responding in the presence of the stimuli on the key was itself under the control of the conditional stimulus. The orderly shift from a pattern of responding in the presence of no illumination, marked by more responding to stimuli containing a red background, to a pattern of responding in the presence of 2 flashes per sec, marked by more responding to stimuli containing triangles, suggests that the pigeons' attention may have been shifted from the color of the background to the character of the figure by the change in the value of the conditional stimulus. This possibility is considered directly in the next part of the experiment. First, however, two additional features of these results warrant brief discussion.

The joint control of responding by the stimulus on the key and the conditional stimulus is particularly revealed by the behavior in the presence of the triangle on the red background, the one stimulus consistently associated with reinforcement under each value of the conditional stimulus during training. The birds tended to respond less in the presence of values of the conditional stimulus which had not been explicitly associated with reinforcement during training. The presence of this generalization strengthens the conclusion that the conditional stimulus was effective in controlling responding jointly with the stimulus presented on the key.

These gradients do not reveal a release from inhibitory properties of extinction when the conditional stimulus is changed from values explicitly associated with extinction during training. When the rate of responding is sufficiently high for a decrease in responding to be detected, the presentation of intermediate or extreme values of the conditional stimulus invariably resulted in a decrease, rather than an increase, in the rate of responding. This occurred with intermediate values of the conditional stimulus for Pigeon 3 in the presence of a circle on a green background and for 3 flashes per sec for all birds in the presence of the circle on a red background. This effect can be interpreted as a decrease in the amount of induction to these stimuli when the conditional stimulus is changed. The present data therefore strengthen the notion that responding in extinction may be modulated up and down by changes in the amount of induction from responding reinforced in the presence of other stimuli (*cf.*, Reynolds, 1968).

Assessment of attention. This part of the experiment was undertaken in order to examine directly the direction of the pigeons' attention in the presence of each of the conditional stimuli used during training. Figure 2 shows, in a separate panel for each bird, the total number of responses emitted in the presence of each of the separate, singly presented aspects of the stimuli on the key (the triangle, the circle, red background or green background) in the presence of the original two conditional stimuli: no light in the chamber (unfilled bars) and two flashes of the houselight per second (filled bars).

If the conditional stimulus controls a simple shift in attention from the color of the background under conditions of no illumination to the character of the figure under conditions of 2 flashes per sec of the houselight, a number of results should be obtained. Figure 2 shows that these expectations are not fulfilled either consistently or on all occasions, nor are the differences in the tendencies to respond as great as found previously in cases of clearly selective attention (Reynolds, 1961). The expectations are stated and evaluated in the following paragraphs.

The triangle should certainly occasion more responses under the flashing condition (filled bars) than in the dark (unfilled bars) because the triangle was always the occasion for reinforcement under the flashing condition. Figure 2 shows that this occurred only with Birds 2 and 3, while the opposite occurred with Birds 1 and 4.

The red key should certainly occasion more responses in the dark (unfilled bars) than in the flashing condition (filled bars) because the red stimulus was always the occasion for reinforcement in the dark. Figure 2 shows that this occurred only with Bird 3, while the opposite occurred with Birds 1 and 4 and the number of responses in the two conditions were equal for Bird 2.

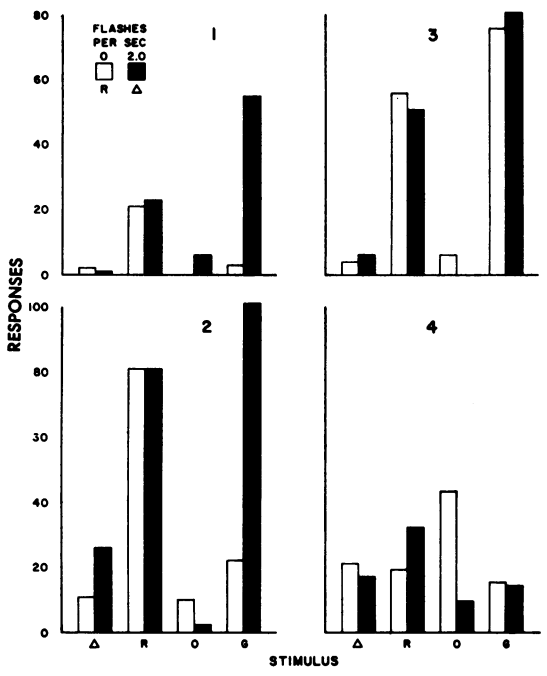

Fig. 2. Assessment of attention for four pigeons. The total number of responses in the presence of each of the separate aspects of the stimulus on the key is shown for two conditions of illumination of the chamber: no illumination (unfilled bars) and flashing light (filled bars).

The circle might also be expected to occasion more responses in the dark (unfilled bars) than in the flashing condition (filled bars) because the circle was never the occasion for reinforcement under the flashing condition. Figure 2 shows, again, that this occurred with Birds 2, 3, and 4, while the opposite occurred for Bird 1, which did not respond at all in the dark.

Finally, the green stimulus might also be expected to occasion more responses under the flashing condition (filled bars) than in the dark (unfilled bars) because the green stimulus was never the occasion for reinforcement in the dark. Figure 2 shows that this occurred with Birds 1, 2, and 3, while the opposite occurred with Bird 4.

In these comparisons, the numbers of responses differ in the expected direction nine times, in the opposite direction six times, and there is one tie. When each bird is considered individually, however, Birds 2 and 3 (except for the tie of Bird 2) fulfill all four expectations, while Birds 1 and 4 do not.

A further analysis of these data casts additional doubt on an interpretation of the generalization gradients simply in terms of a shift in attention. Since the color red on the key was consistently associated with reinforcement in the dark condition (unfilled bars), the red key should occasion more responses than the green key. Figure 2 shows that while this was true for Birds 1, 2, and 4, Bird 3 pecked more on green. Moreover, Bird 4 pecked more frequently on the forms, which had not been consistently associated with reinforcement in the dark. In the flashing condition (filled bars), since the triangular form is consistently associated with reinforcement, the triangle should occasion more responses than the circle. Figure 2 shows that while this was true for Birds 2, 3, and 4, all four birds pecked more frequently on the colored keys not consistently associated with reinforcement.

These surprisingly high response rates on the colored stimuli, especially the green, argue against an interpretation on the basis of shifts in selective attention. Nevertheless, the responding on the green stimulus did not, in

six of the eight cases, obscure relationships predicted by selective attention: green occasions more responses than red in the dark, and the triangle occasions more than the circle in the flashing light.

Note also that Bird 4, the exception to complete color predominance, responded more to forms in the dark and to red in the flashing light, both of which were inappropriate to the overall reinforcement conditions. Nevertheless, this bird displayed some evidence of shifts in attention.

The data presented earlier on generalization demonstrated control over responding in the presence of the compound stimuli on the key by the conditional stimulus. The question to be raised now concerns the way in which that control is exercised.

It is clear from the present data that a single answer may not suffice for all four birds. This should not be surprising, because there have been demonstrations (*e.g.*, Reynolds, 1961) that attention may be capriciously directed. Although the conditional stimuli and their correlations with reinforcement would seem to have given the bird added reason for coming selectively under the control of particular aspects of the stimuli on the key, the analysis of Fig. 2 shows that radical shifts in attention did not occur when the conditional stimulus was changed. There is some evidence that Birds 2 and 3 tended to change the aspect of the stimuli on the key to which they attended in the presence of the conditional stimuli, but the magnitude of the shift, as measured by the differences in the number of responses, was not large. The attentional shifts observed in Birds 2 and 3 appear to be confined to either the figural stimuli or to the ground stimuli. However, both of these birds responded more frequently to the colors under conditions in which form was consistently associated with reinforcement. Birds 1 and 4 show no consistent evidence of a shift in attention.

This procedure established control of responding to compound stimuli by conditional stimuli as evidenced by the measurements of generalization to various values of the conditional stimulus. In addition, it may have been successful in controlling the attention of at least some of the subjects to some extent. It is not, however, an attention-controlling procedure of great power; the shifts in attention were not large and did not occur significantly in at least two subjects.

Perhaps a combination of extended training, different stimuli, and more sensitive procedures for testing attention would result in consistent and sizeable shifts in selective attention. However, the present data show that orderly generalization gradients and control by compound stimuli can be produced without consistent shifts in attention between the figure and ground aspects of compound stimuli.

The suprising lack of attentional shift in these pigeons contrasts with the apparent ease of human observers to shift attention between figure and ground in response to conditional stimuli.

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